

PATENT SPECIFICATION

DRAWINGS ATTACHED

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COMPLETE SPECIFICATION

Improvements relating to Variable Reluctance Electrical Machinery

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Belloy, Le Vesinet, France, both of French
Nationality, do hereby declare the invention
for which we pray that a patent may be
granted to us, and the method by which it is
to be performed, to be particularly described
in and by the following statement:—
- 5 This invention relates to dynamo electrical
machines and more particularly to electric
machines of the type disclosed by the same
Applicants in British Specification No.
940,233.
- 10 This Specification relates to variable-
reluctance electrical machinery having the
main feature that the mean saturation induc-
tion of the rotor teeth is reduced to some
15 15 to 85% of the maximum induction chosen
for the magnetic circuit of the machine in
order that relatively strong magnetic fields
may be used in the main air gaps without
excessive losses, so that the machinery has a
high power-to-weight ratio. To this end, the
20 rotor are formed by alternate magnetic and
non-magnetic layers, for instance, pure iron
laminations separated by layers of air.
- 25 In one embodiment of the aforesaid patent
specification the stator comprises at least two
30 identical pole pairs, each pole having an
angular span or width a and the space between
consecutive poles having an angular extent b ,
and the moving part comprises teeth having
an angular extent of substantially $a+b$.
- 35 When a machine of this kind which has two
pairs of poles is used as an alternator, each
pole is magnetised through the agency of at
least one winding, one end of which is sup-
plied with exciting d.c. while the other end
40 is connected to a line through which flows
the a.c. produced by the alternator, the ends
of two contiguous windings being intercon-
nected and arranged as a bridge circuit so
that the exciting d.c. is supplied via one shunt
arm of the bridge and the a.c. passes through
the other shunt arm. Consequently, the flux
variations which are produced in two con-
secutive poles by a tooth of the moving part
moving past such poles are always equal and
opposite, and so, since the voltage induced
at the two ends of the d.c. shunt arm is
always substantially the same, only a low
unwanted a.c. flows in the alternator excita-
tion line; also, since the a.c. voltages induced
at the two ends of the a.c. shunt arm always
vary oppositely, all the mechanical energy
supplied to the alternator rotor is in theory
converted into useful electric current, less
normal iron and copper losses.
- It has been found that this embodiment,
however, that perfect separation between the
magnetic circuits of the two pole pairs is
impossible, and so the ideal conditions just
outlined cannot be approached closely enough
for optimum efficiency of the machine.
- It is an object of the present invention to
improve the efficiency and range of uses of
electrical machines having the main feature
of the aforesaid patent specification. A feature
of this invention is separation of the magnetic
circuits of consecutive stator poles, and a
corresponding division of the rotor into two
parts rigidly secured to one another.
- According to the invention, the rotor is
divided perpendicularly to its axis into two
half-rotors rigidly interconnected to one
another, and the stator is divided into two
half-stators, each of which corresponds to a
half-rotor and comprises at least one pole
pair opposite the corresponding half-rotor; all
the poles of each half-stator have the same
width and each half-stator pole has a wind-
ing, one end of which is connected to the
winding of the pole of the same pair, while

the other end is connected to the winding of a pole of the other half-stator; and each half-rotor has as many toothed pairs as each half-stator has pole pairs, each tooth having substantially the same width as each pole, the relative arrangement of the poles and of the teeth being such that the sum of the angles of that part of a tooth of the first half-rotor which is opposite a particular pole, and of that part of a tooth of the second half-rotor which is opposite a pole whose winding is connected to one end of the penultimately mentioned pole, is always equal to the width of each individual pole.

According to another feature of the invention, in machines having two pole pairs, the teeth of the second half-rotor can be staggered by $\pi/2$ relatively to the teeth of the first half-rotor, in which event the pole pairs are parallel with one another; the stator can then be produced from oriented-grain laminations, with a consequent improvement in the power-to-weight ratio.

An advantage of an electrical machine having two pole pairs according to the invention when used as an alternator in which the points common to the windings of each pole pair are respectively connected to a d.c. exciting source and the a.c. produced by the alternator is delivered between the places common to the other ends of the last-mentioned windings, as set forth in the aforesaid patent application, is that the current which the a.c. circuit can provide is limited to the current delivered by the exciting source because of the demagnetising ampere turns of the output a.c.; in the event of the a.c. output being short-circuited, the demagnetising ampere-turns just mentioned become equal to the magnetising ampere-turns of the exciting circuit, and so it is impossible to overload the alternator.

One particular advantage of an alternator according to the invention is the readiness with which it can be regulated, for a slight variation in exciting current can produce a large variation in output. More particularly where a component of the exciting current is proportional to the output current, effective regulation can be provided by variation of a small external current. Another advantage of electrical machines according to the invention is that, since the exciting windings are connected in series, the machine can operate as a universal motor if the exciting windings are short-circuited alternately in synchronism with motor rotation, overvoltages being reduced considerably by the inductance of the winding in series with the shortcircuited winding.

In the aforesaid patent specification, the magnetic characteristics of the teeth of the moving part are constant throughout their width. More particularly, in the embodiment of an alternator described in such

patent application, where the rotor teeth have a substantially parallelepipedic shape, like the stator poles past which the rotor teeth move, they increase in magnetic flux when a tooth starts to pass a pole, and the decrease in magnetic flux when a tooth starts to leave a pole, are constant and proportional to the angular displacement of the rotor; consequently, the voltages produced in the stator windings as a tooth passes a pole have consecutively two opposite and substantially constant values at least during low-load or no-load operation. The output from an alternator of this kind operating under these conditions is substantially rectangular, a factor which may be disadvantageous for supplying some networks or where the machine is required to operate as a synchronous motor on a supply providing a sinusoidal current.

It is an object of the invention to obviate this disadvantage.

A feature of the electrical machine according to one particular embodiment of this invention is that their teeth are so devised that their mean density of magnetic metal decreases substantially sinusoidally on either side of the tooth axis. In one particular embodiment of variable-reluctance electrical machines according to this invention, each rotor tooth is formed by substantially rectangular profile laminations having an angular span less than the angular span of the stator poles and more than half the last-mentioned angular span, the rotor tooth laminations being staggered fanwise so that together they have the same angular span as the stator poles or a slightly smaller angular span, so that the mean density of magnetic material is greater near the tooth axis—where such density corresponds to the sum of the thicknesses of the laminations forming the tooth for a given thickness of dielectric, for instance, air—and decreases stepwise to a minimum at the tooth ends.

This feature, which enables the voltage induced in the stator windings to be varied in accordance with any desired pattern, more particularly sinusoidally, is of use not only in alternators and synchronous motors but also in d.c. motors in which the stator windings are switched in synchronism with rotor rotation, for the use of teeth according to the feature just described on two rotors angularly offset from one another by half a tooth evens out the torque and improves the conditions for synchronous switching.

For a better understanding of the invention and to show how the same may be carried into effect, reference may now be made to the accompanying drawings wherein:

Fig. 1 diagrammatically illustrates in axial section a four-pole electrical machine according to the invention in alternator form;

Fig. 2 is a perspective view of the machine illustrated in Fig. 1, in section along the

line II—II of Fig. 1 and with one-quarter of the stator removed to show the rotor;

Fig. 3 diagrammatically illustrates the arrangement of a rotor tooth of a machine according to one particular embodiment of the invention, and

Fig. 4 is a perspective view similar to Fig. 2 with the rotor teeth devised similarly to the arrangement shown in Fig. 3.

Referring to Figs. 1 and 2, a stator 31 of alternator of the type having an unwound toothed rotor comprises a group of magnetic laminations 32 which can be of the oriented-grain kind, and has four identical poles 33a, 33b, 33c, 33d having an angular span $\pi/2$. Pole 33a is in alignment with pole 33d, and pole 33b is in alignment with pole 33c; pole 33b is opposite pole 33a, and pole 33c is opposite pole 33d. Each pole has a winding 34a, 34b, 34c, 34d; the four windings are identical and can withstand the alternator excitation current and the a.c. output together.

The moving part or rotor comprises two parts or half-rotors 38₁, 38₂ disposed on a single shaft 39. Each half rotor 38₁, 38₂ is formed in the fashion set forth in the afore-said patent specification—i.e., by a group of magnetic laminations 28a, 30a; in two diametrically opposite segments extending over approximately $\pi/2$, the laminations 28a have a diameter greater than the diameter of the laminations 30a so that there are air spaces 29a between those parts of the laminations 28a which extend beyond the laminations 30a. These extending parts of the laminations 28a are aligned on each half-rotor to form teeth 40a₁ and 40b₁ of the half-rotor 38₁ and teeth 40a₂ and 40b₂ of the half-rotor 38₂. The teeth 40a₁, 40b₁ of the half-rotor 38₁ are staggered by $\pi/2$ relatively to the teeth 40a₂, 40b₂ of the half-rotor 38₂. Consequently, the sum of the opening angles of those parts of the teeth 40a₁, 40a₂ and of the teeth 40a₂, 40b₂ which are at any time associated with a pole is constant and equal to $\pi/2$. As the rotor rotates, the magnetic flux variations produced in the poles 33d and 33a are therefore always equal and opposite, as are the flux variations which are simultaneously produced in the poles 33c, 33b. The voltages induced by these flux variations in the respective windings 34a, 34b and 34c, 34d are therefore always equal and opposite.

When a bridge circuit arrangement I, J, K, L is used as shown in Fig. 1 where the windings 34a, 34b are connected in parallel to one terminal of an excitation source 37 and in series with the windings 34d, 34c which are connected in parallel to the other terminal of the source 37 and the alternator output is taken from the place L common to the windings 34a, 34d and from the place J common to the windings 34b, 34c, it will be apparent that, since the voltages induced at the ends of the bridge shunt arm I—K

are always equal and of the same sign, no a.c. reaches the excitation line; also, since the voltages induced at the ends of the shunt arm J—L are equal and of opposite phase, all the mechanical energy supplied to the rotor 38 is transduced to the output line in the form of a.c., less normal iron and copper losses. This result, which depends, of course, upon the teeth of the rotor 38 being saturated while the other parts of the alternator are not saturated, is helped by the separation between the magnetic circuits of the poles which experience flux variations in opposite directions.

Fig. 3 illustrates by way of non-limitative example, in plan and in elevation, a tooth of a rotor 40, such tooth being formed by four identical and coaxial groups a, b, c, d each comprising four pure iron laminations, as 42a, 43a, 44a, 45a which are staggered relatively to one another by an equal amount equal to one-fifth of their length so that each group, and therefore the tooth, have a length equal to eight-fifths of the length of each lamination. The laminations, as 42a, are substantially rectangular extensions, of height h, of pure iron laminations forming, together with circular laminations 45 which separate from one another and frame the groups a, b, c, d, the complete rotor 40, only some of which is illustrated.

Along the tooth axis—i.e., at the place where the passage past a pole is required to give the greatest variation in reluctance flux—the mean density of metal corresponds substantially to four thicknesses of iron for a single thickness of air layer separating the groups—i.e., to 4/5. Between one-eighth and two-eighths of tooth length on either side of its axis, the mean density of metal corresponds to three thicknesses of iron for two thicknesses of air layer—i.e., to 3/5, between two-eighths and three-eighths to 2/5, and between three-eighths and four-eighths to 1/5. In other words, this variation of the mean density of magnetic metal along tooth length, and the corresponding variation in saturation induction, are substantially sinusoidal.

Fig. 4 differs from Fig. 2 only in the details of rotor construction, which is as illustrated in Fig. 3. Fig. 4 shows how a tooth is formed by fanwise-staggered extensions, as 41a, 42a, 43a, 44a, of groups of four laminations forming four elements a, b, c, d of a rotor tooth and framed and separated by circular laminations, as 45.

WHAT WE CLAIM IS:—

1. An electrical machine of the type having an unwound toothed rotor and in which a stator has at least two pairs of electromagnetic poles and a rotor has at least two pairs of teeth formed by thin iron laminations separated from one another by non-

magnetic zones, for instance, of air, wherein the rotor is divided perpendicularly to its axis into two half-rotors rigidly secured to one another, each such half-rotor comprising at least one pair of teeth, and the stator is divided into two half-stators, each of which corresponds to one half-rotor and comprises at least one pair of poles opposite the rotor.

2. A machine as set forth in claim 1 wherein all the poles of each half-stator have the same angular span and each half-stator pole has a winding, one end of which is connected to the winding of the pole of the same pair, while the other end is connected to the winding of a pole of the other half-stator.

3. A machine as set forth in claim 2 wherein each half-rotor has as many tooth pairs as each half-stator has pole pairs, each tooth having substantially the same angular span as each pole, the relative arrangement of the poles and of the teeth being such that the sum of the angles of that part of a tooth of the first half-rotor which is opposite a particular pole, and of that part of a tooth of the second half-rotor which is opposite a pole whose winding is connected to one end of the penultimately mentioned pole, is always equal to the angular span of each individual pole.

4. A machine as set forth in claim 3 wherein each half-stator comprises a pair of poles and each half-rotor comprises a pair of teeth and the teeth of each half-rotor are staggered by $\pi/2$ relatively to the teeth of the other half rotor, and the stator pole pairs are parallel with one another.

5. A machine as set forth in claim 4 wherein each half-stator is formed by oriented-grain laminations.

6. A machine as set forth in claim 1 wherein the rotor teeth are so devised that their mean density of magnetic metal decreases substantially sinusoidally on either side of their axis.

7. A machine as set forth in claim 6 wherein each rotor tooth is formed of substantially rectangular profile laminations having an angular span less than the angular span of the stator poles and more than half the last-mentioned angular span, the rotor tooth laminations being staggered fanwise so that together they have the same angular span as the stator poles or a slightly smaller angular span, so that the mean density of magnetic material is greatest near the tooth axis—where such density corresponds to the sum of the thicknesses of the laminations forming the tooth for a given thickness of dielectric, for instance, air—and decreases stepwise to a minimum at the tooth ends.

8. An electrical machine substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

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FIG.1

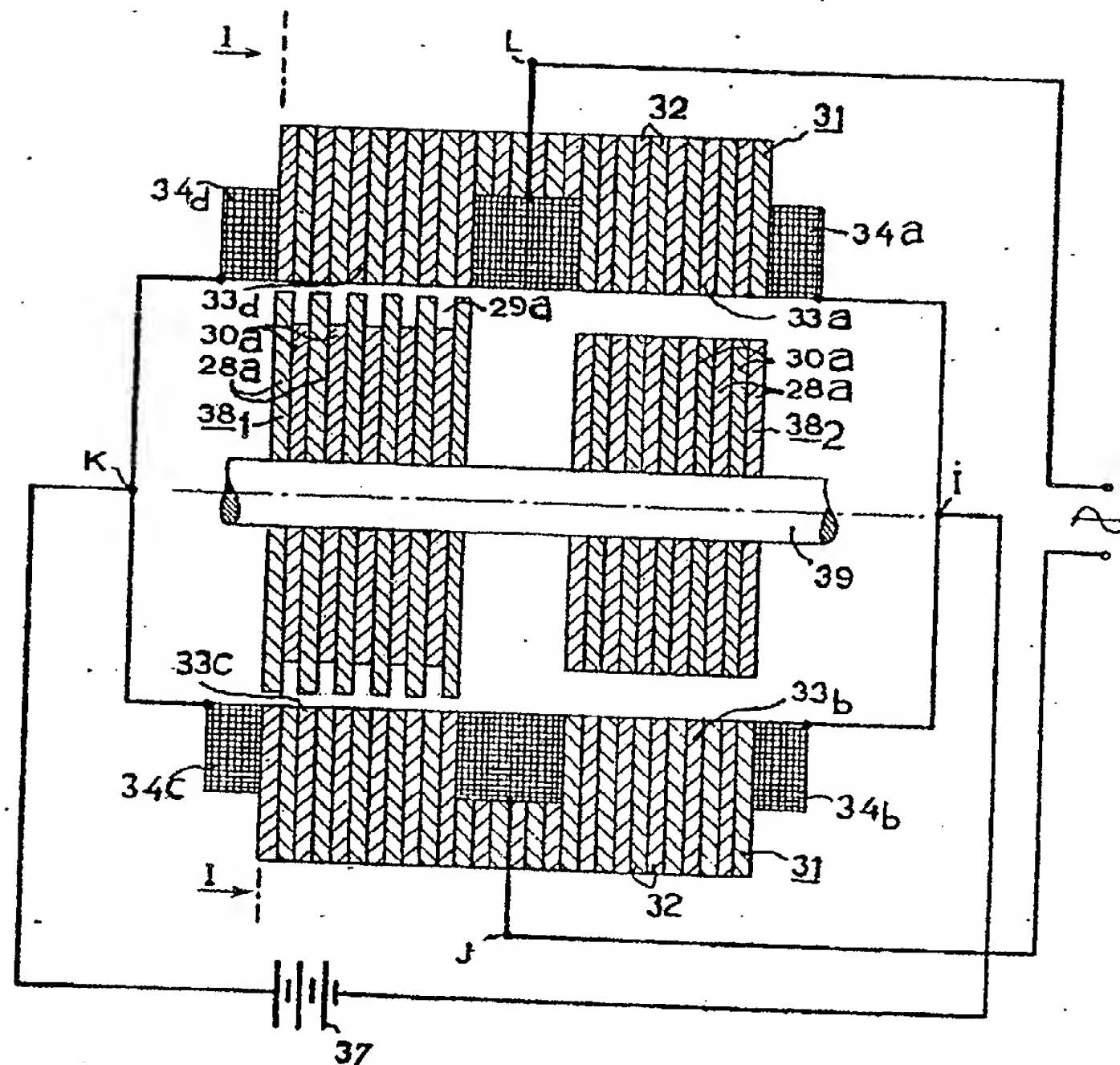
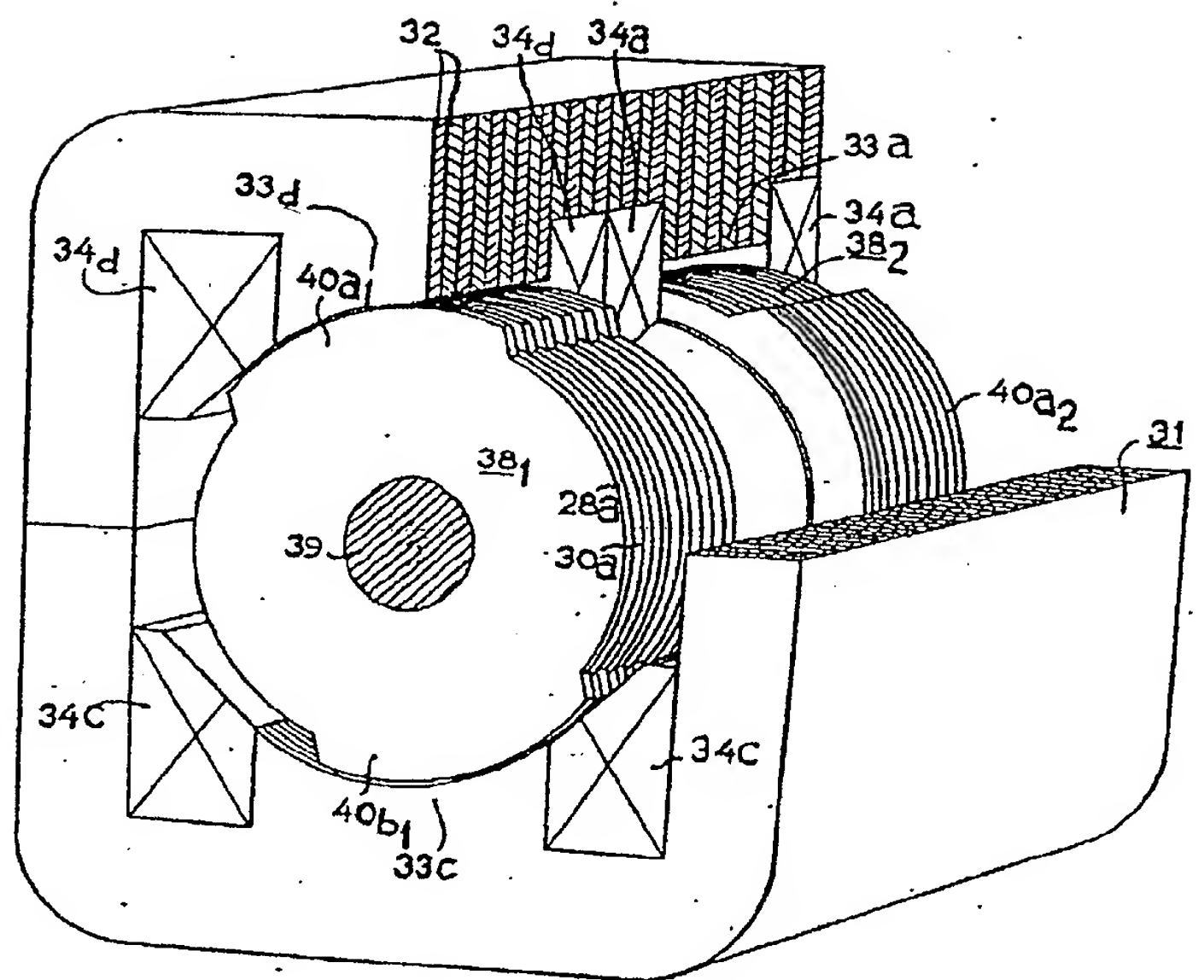


FIG. 2



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COMPLETE SPECIFICATION

3 SHEETS

This drawing is a reproduction of
the Original on a reduced scale
Sheets 2 & 3

FIG. 3

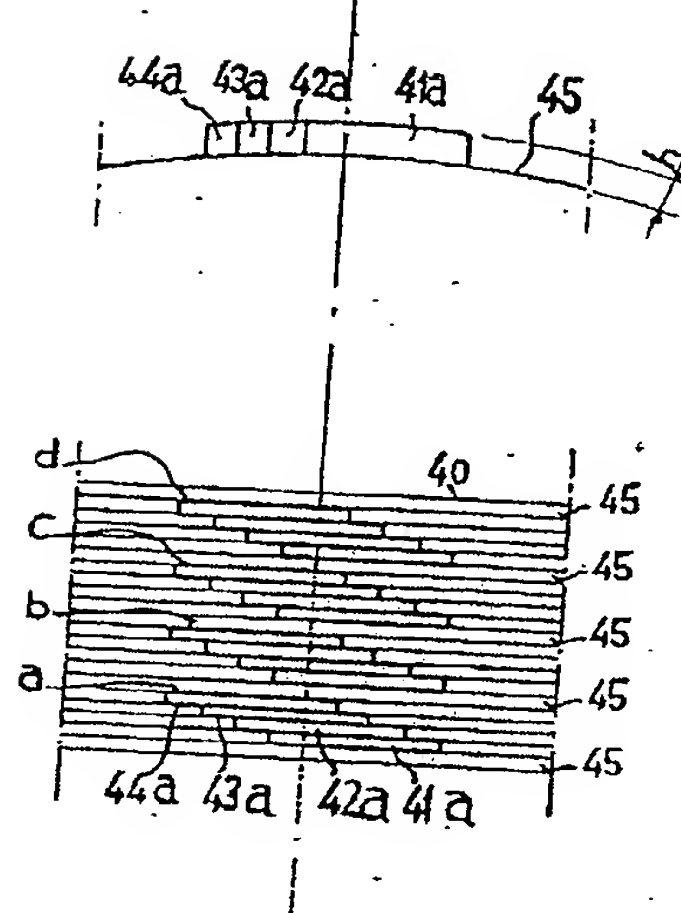


FIG. 4

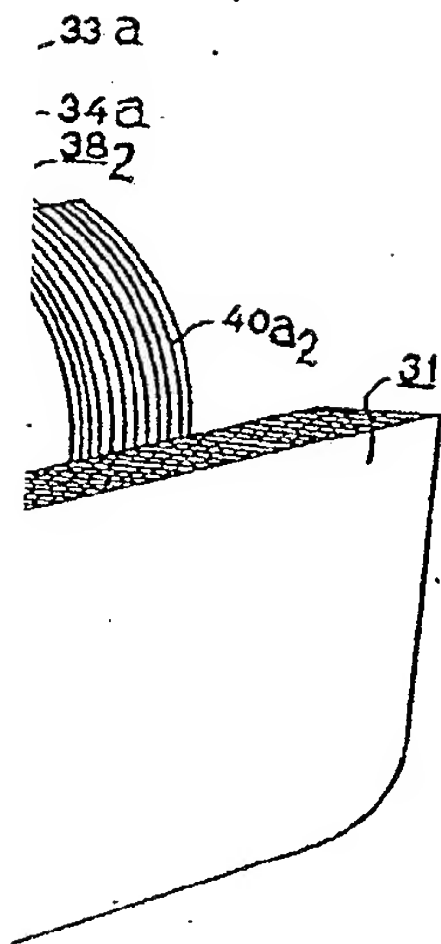
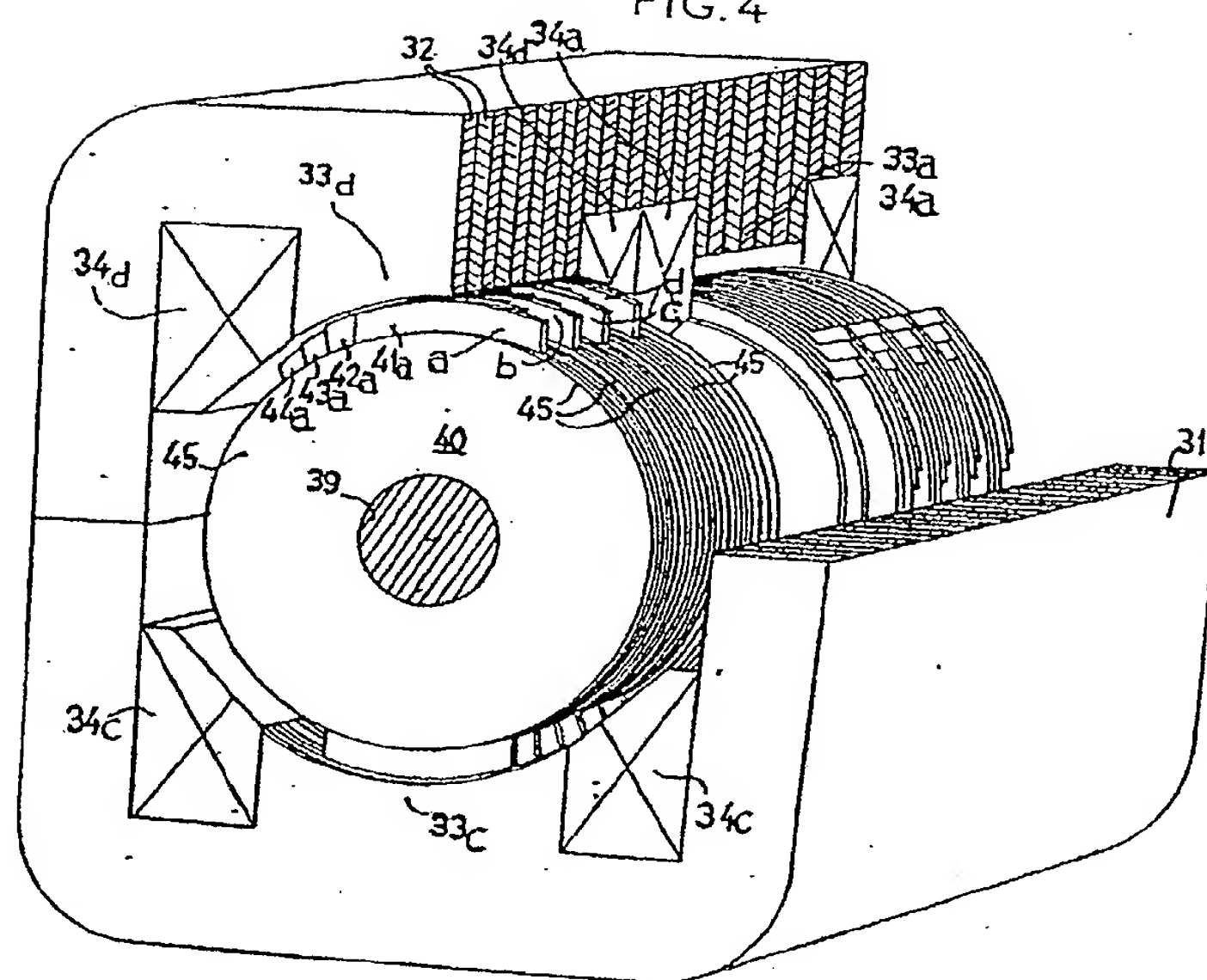


FIG. 3

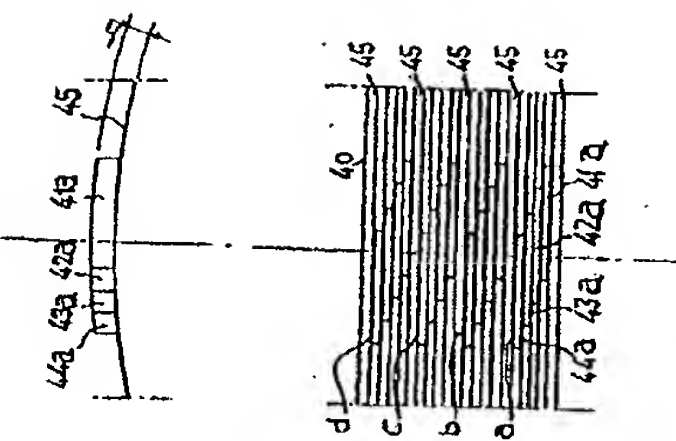


FIG. 4

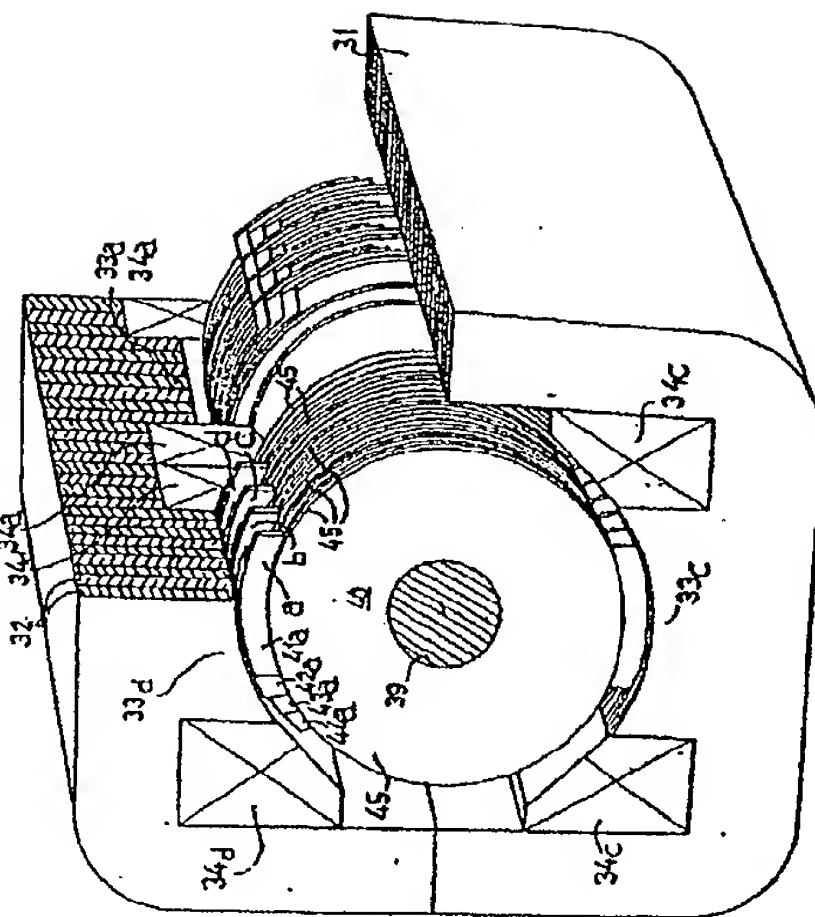


FIG. 2

